Lightning protection
‘Separation Distance’ concept

Trevor Manas, Pontins

An isolated Lightning Protection System (LPS) prevents partial lightning currents from entering protected space via electrical equipment or plant, in areas that are vulnerable to direct lightning strikes.

The ‘Separation Distance’ concept is the measures employed when an Isolated Air Termination System is required. In accordance with the SANS / IEC Code 62305 [1] series: ‘An isolated external LPS should be used when the flow of the lightning current into bonded internal conductive parts may cause damage to the structure or its contents’.

In other words, an isolated LPS should be installed to prevent partial lightning currents from entering into protected space via electrical equipment or plant situated in areas that are vulnerable to direct lightning strikes. The uncontrolled entry of partial lightning currents into a structure can lead to flashovers between the LPS and the internal conductive elements of the structure. This will result in the risk of fire and damage to internal systems being unacceptably high. The correct separation distance therefore must be maintained to prevent these flashovers.

**Isolated LPS and separation distances**

Special problems occur when plant and equipment are installed to roofs and these elements are vulnerable to direct lightning strikes. These vulnerable elements require additional protection measures. If the roof mounted plant and equipment are connected directly to the external LPS, then, in the event of a direct lightning strike, partial lightning currents are conducted into the structure. This could result in the destruction of surge sensitive equipment, the increase of step and touch hazards and the increased risk of fire within the structure. Direct lightning strikes to the roof-mounted equipment can be prevented by having an isolated air termination system. An isolated air termination system is achieved by calculating and maintaining a separation distance ‘s’ between the equipment and the air terminal. The separation distance must therefore be taken into account when dimensioning the air termination system.

**LEMP versus induced surges**

The need to prevent partial lightning currents from entering a protected space is critical in providing effective protection solutions for equipment and people. It is therefore important to understand the difference between a lightning fault current and an induced surge current.

A lightning fault current has a waveform of 10/350 microseconds and an induced surge current has a waveform of 8/20 microseconds. The waveforms are as per the IEC 61643-11 [2] requirements, for the LEMP waveform it would take 10 microseconds to reach its peak current of 40 kA and then 350 microseconds to reach half of its magnitude of 20 kA. As can be clearly seen, the duration that electronic equipment...
would be vulnerable to damage is far greater for a lightning induced current than for an induced surge current. It is also much easier to protect equipment from induced surges than LEMP.

**LEMP versus induced surges.**

**Separation distance calculations**

There is a risk of uncontrolled flashovers between components of the external LPS and metal and electrical installations within the structure. Metal installations such as water pipes, aircon ducts and electrical power lines produce induction loops in the structure which are induced by impulse voltages due to the rapidly changing lightning magnetic field. These impulse voltages must be prevented from causing uncontrolled flashovers which can cause fire. In addition, flashovers on electric power lines can cause enormous damage to the installation and the connected consumers. The potential difference increases with height, therefore the longer the down conductor distance, the larger the separation distance (see Figure 1.1).

The separation distance is calculated using the following formula:

\[
s = k_i \left( \frac{k_c}{k_m} \right) \cdot L (m)
\]

- \(k_i\) is a function of the class of LPS chosen (induction factor)
- \(k_c\) is a function of the geometric arrangement (current splitting coefficient, number of down conductors)
- \(k_m\) is a function of the material in the point of proximity (material factor for isolation)
- \(L (m)\) is the length of the air-termination system or down-conductor system from the point at which the separation distance shall be determined to the next point of equipotential bonding

In accordance with SANS / IEC 62305 Part 3 [1] the following values are given:

**Value of Ki – Lightning Protection Level (LPL)**
- LPL 1 = 0,08
- LPL 2 = 0,06
- LPL 3 = 0,04
- LPL 4 = 0,04

**Value of Km (insulation level)**
- Air = 1
- Bricks, masonry etc. = 0,5

**Value of Kc**
The calculation of \(K_c\) is often difficult because the current splitting coefficient will be different for different types of structures

- **Single air terminals:** If a single air terminal is erected close to the structure then the \(K_c\) factor equals one (see Figure 1.2) and can be applied directly to the formula

\[
k_c = \frac{h + c}{2h + c}
\]

- \(h\) – Length of the down conductor
- \(c\) – Mutual distance of the air termination masts

**Roofs with two down conductors**
The following formula indicates the calculation required for a LPS with two down conductors which are connected together at roof level. The interconnection of air terminals vastly improves the current division capabilities and therefore reduces the separation distance.

\[
k_c = \frac{h + c}{2h + c}
\]

- \(h\) – Length of the down conductor
- \(c\) – Mutual distance of the air termination masts
Roofs with four down conductors

The following formula indicates the calculation required for a LPS with four down conductors which are connected together at roof level. The more down conductors, the better the current division, this calculation is used for both flat and gabled roofs.

\[ k_c = \frac{1}{2n} + 0.1 + 0.2 \cdot \sqrt{\frac{c}{h}} \]

**Value of Kc**

**Tall structures**

The taller a structure is the more difficult it would be to obtain a separation distance that would be practical to install, (i.e. a calculated separation distance could be as much as 300 cm or 400 cm from the structure).

To alleviate this problem the down conductors are equipotentially bonded together at various levels along the structure’s height.

The supplementary ring conductors are installed to balance the lightning current and to improve the current division over a larger area. The principle of using the additional ring conductors (see Figure 1.6), can only be applied when installing ring type or meshed type (Type B) earth termination systems. In addition, Class 1 lightning arresters must be installed at the height of each supplementary ring conductor. If the total separation distance \( S_{tot} \) is to be determined, then the following formula must be used for the calculation:

\[ S_{tot} = \frac{k_c \cdot l_{tot} + k_c \cdot l_3 + k_c \cdot l_4}{k_c} \]

**How to maintain the required separation distance**

Once the required separation distance has been calculated, there are various methods which can be employed to ensure that the correct isolation has been achieved. These methods of creating the correct separation distance are as follows:

- Separation by means of placing the air terminals the required distance away from the conductive elements
- Separation of lightning conductors by means of insulating material - Glass-fibre Reinforced Plastic (GRP)
- Separation by means of High Voltage Impulse (HVI) conductors

**Separation distance methods**

**Physically separated air terminals**

For smaller roof mounted structures like small fans, air conditioners and small plant the protection can be achieved by installing individual or a combination of several air termination rods. The air terminals must be installed at the calculated separation distance away from the roof mounted structure.

**GRP insulators**

The DEHNiso is a modular type isolation system which allows for the installation of isolated LPS for virtually any type of structure. Isolation is achieved via GRP rods which range between 300 mm and 1 000 mm in length and can be installed directly onto the structure. The DEHNiso system is suitable for all types of air termination and down conductor...
systems. The GRP rods have a $K_c$ (insulation) value of 0.7 which is to be used for the separation distance calculations.

Separation by means of HVI conductors

HVI conductors are equipped with a special external coating which allows the diverting of high lightning impulse voltages to a reference potential. This trapping area is called the ‘sealing end’, which typically has a length of 1.5 m, thereafter the lightning current is trapped within the inner core of the HVI conductor. This technology allows for the installation of lightning conductors directly onto the equipment which is to be protected. There are three different types of HVI conductor; each with its own equivalent separation distance as follows:
- HVI light separation distance = 45 cm in air and 90 cm with bricks
- HVI long separation distance = 75 cm in air and 150 cm with bricks
- HVI power separation distance = 90 cm in air and 180 cm with bricks

HVI conductors offer effective and aesthetically pleasing solutions on projects where the separation distances are difficult to achieve. HVI conductors are also suitable for hazardous areas.

When can separation distances be ignored?

Under certain circumstances, the separation distance can be ignored:

*Use of concrete steel reinforcing:* If the concrete steel reinforcing is used as natural down conductors, then the separation distance for the down conductor system can be ignored. This is due to the fact that by using the rebar we are literally creating thousands of parallel paths to earth, this would enhance the current division to such an extent that only a minor fraction of lightning current would be flow near to the internal conductive elements. This practice is acceptable provided that care has been taken to ensure electrical continuity across the rebar as described in SANS / IEC 62305 Part 2 item 5.3.5 [1]. This practice only applies to down conductor systems.

*Use of structural steelwork:* The use of the interconnected structural steelwork of large steel structures will result in sufficient enhanced current division to allow for the installation of a non-isolated down conductor system. The use of the structural steelwork does not eliminate the need for isolated air terminals if there is plant or equipment on the roof structure.

*Use of lightning current arresters:* In cases where the calculated separation distance cannot be achieved, the use of lightning current arresters should be considered.

This approach only applies for rooftop structures that are only fed with electrical or data cables. Rooftop structures with ducting or piping that enter into the building would still allow partial lightning currents to enter into the building via the ducting or piping. Even if rooftop distribution panels are equipped with lightning current arresters they still require additional external protection via air terminals to prevent direct strikes to these elements. The only difference is that the air terminals would not be separated. The use of the natural elements of the structure will enhance the current division of the lightning current and therefore eliminate the need to isolate or separate the down conductor system. This results in substantial savings on the installation costs and results in a far more effective LPS. The installation of lightning current arresters instead of an isolated air termination system is not recommended as it is more costly and less effective. It should therefore only be used under exceptional circumstances where the separation distances cannot be achieved.

References


Trevor Manas started his lightning protection career at Pontins in 1991 as an installation technician, learning the ropes by working on various sites and doing physical installations. Within two years, he was promoted to a sales engineer position, where he was involved in site assessments, soil resistivity surveys and compiling quotations. In 1996, Trevor was promoted to the position of director and was in charge of ensuring the company’s compliance with the earthing and lightning protection codes of practice. In 1999, Trevor became the managing director of Pontins and under Trevor’s guidance the company has strived to offer protection solutions for some of South Africa’s largest and most prestigious projects. In 2013, Pontins formed a partnership with DEHN Africa which gave Pontins access to world class cutting edge lightning protection technologies. Enquiries: Email trevor@pontins.co.za